

Continental J. Fisheries and Aquatic Science 2: 6 - 12, 2008
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A MESOCOSM ANALYTICAL STUDY ON THE IMPACT OF FRESHWATER MUSSEL
(*LAMELLIDENS MARGINALIS* LAMARCK) MEDIATED BIOTURBATION AND BIODEPOSITION ON
SOME ECOLOGICAL FACTORS OF A FRESHWATER LAKE

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ABSTRACT

The biotic potential of the benthic filter feeding freshwater bivalve mollusc *Lamellidens marginalis* (Lamarck) influencing the nutrient dynamics of the bottom sediments of the lake by means of biodeposition and bioturbation activities were analysed using a lake mesocosm experiment. Five control as well as experimental mesocosms was maintained up to 60 days (d). The factors studied included the percentage of water content of the sediment, percentage of total nitrogen, percentage of organic matter along with the total phosphorus and humic acid content. While total phosphorus and humic acid content of the experimental mesocosms showed gradual and significant increases from 30d of the experiment to reach the maximum levels after 60d, the percentage of organic matter registered significant increases right from 15d onwards and reached the maximum values after 60d. On the other hand, while the percentage of water content of the sediments of the experimental mesocosms increased only up to 30d experiment, percentage of nitrogen was increased during the first half and at the fag end of the experiment. All the investigated ecological factors were found to be significantly influenced by the presence of *L. marginalis* in the experimental mesocosms. The study indicated that the mussel influence the nutrient dynamics of the inhabitant ecosystem through the processes of excretion, biodeposition of pseudofaeces and faeces, along with the bioturbation of the sediments brought about by their ploughing movements.

KEYWORDS: freshwater mussel, *Lamellidens marginalis*, bioturbation, biodeposition, mesocosms.

INTRODUCTION

The freshwater mussel (*Lamellidens marginalis* Lamarck) is a benthic filter feeding organism and is continuously exposed to the water, suspended particles in the water column and bottom sediments. The biotic potential of *L. marginalis* even though largely remains un-attended, plays very important roles in the ecosystem functions. According to Vaughn and Hakenkemp (2001), freshwater bivalves have the potential to strongly influence the ecosystem processes in freshwater systems. This also holds true with *L. marginalis* because of their characteristic filter feeding and ploughing movements through the bottom sediments. While filter feeding is an important means of removing particles including plankton suspended in the water column (Widmeyer and Bendell-Young, 2007) and biodepositing it to the bottom sediments as faeces and mucous bound pseudofaeces, the ploughing movements and burrowing activity brings in active bioturbation of the medium leading to sediment mixing, improved oxygen penetration and affects other ecological functions. Due to all these activities mussels can repack nutrients and act as a nutrient source for other benthic organisms (Christian *et al.*, 2008).

Unionid mussels are historically important bioturbating macrobenthic organisms and as they can move and disturb large amounts sediments, they may be designated as “biological bull dozers”. They reportedly burrow themselves and mix the bottom sediments (Vaughn and Hakenkemp, 2001). The digging and burrowing activities of *L. marginalis* leading to the bioturbation of the bottom sediments is a form of ecosystem engineering. However, according to Vaughn and Hakenkemp (2001), uncertainty over the extent and importance of sediment-related ecological processes performed by bivalves represent the most significant gap in our understanding of the role of burrowing bivalves in freshwater ecosystems. The influence of bioturbators in altering the conditions at the sediment water interface is reported to be due to the biogenic mixing of sediments (Christian *et al.*, 2004; Solan *et al.*, 2004; De Haas *et al.*, 2005). In this context, attempts have been made in this work to understand the ecological importance of bioturbation and biodeposition by the freshwater mussel *L. marginalis* through a lake mesocosm experiment.

Table 1. Sediment sampling schedule for the control and experimental mesocosms after the expiry of 15, 30, 45 and 60 days

To be sampled from the control mesocosm			Parameter	To be sampled from the experimental mesocosm		
C ₁	C ₂	C ₃	% Water content	E ₁	E ₂	E ₃
C ₂	C ₃	C ₄	% Total nitrogen	E ₂	E ₃	E ₄
C ₃	C ₄	C ₅	% Organic matter	E ₃	E ₄	E ₅
C ₄	C ₅	C ₁	Total phosphorus	E ₄	E ₅	E ₁
C ₅	C ₁	C ₂	Humic acid	E ₅	E ₁	E ₂

Note: Three samples each were taken from each of the mesocosm on each sampling interval

MATERIALS AND METHODS

Setting up of mesocosm

In order to study the influence of bioturbation and biodeposition by the freshwater mussel *L. marginalis* on selected ecological factors of the freshwater lake ecosystem, a lake mesocosm experiment was done in the Srinivasapuram lake (10 ha. area) in the Denkanikottai taluk of Krishnagiri district, Tamilnadu, India. Setting up of the mesocosms was done in the month of February 2008 and was maintained up to May 2008. Altogether ten plastic mesocosms were setup. Five of them (*viz.*, C₁ to C₅) were used as controls and the remaining five (*viz.*, E₁ to E₅) were used as experimental mesocosms. A distance of about 5 m was maintained between the mesocosms and the duration of the experiment was 60 days (d).

Each plastic mesocosm was having a diameter of 87.2 and 100 cm height. They were fixed in the shallow region of the lake in such a way that each of them contained about 30 cm of fine sediments of the lake bottom, carefully avoiding any unaccounted *L. marginalis*, other macro invertebrate fauna or fish. However, the benthic infaunal invertebrates of the lake bottom *viz.*, nematodes, oligochaetes, chironomids and small snails of 2 to 3 mm size along with the soil bacteria were left undisturbed both in the control as well as experimental mesocosms. In the present study, even though a sediment depth of 30 cm was maintained, *L. marginalis* was never found burrowing below 7 cm. Each of the mesocosms was provided with 32 holes (2 cm dia.) above the sediment level and was covered with a nylon net having about 4 mm² mesh to allow the free flow of water and movement of other infaunal benthic micro invertebrates while preventing the entry of fishes and other macro invertebrates. The top of each mesocosm was about 10 to 13 cm above the water surface and each of them had a sediment surface area of 0.6 m². In this condition, all the mesocosms were allowed to equilibrate with the surroundings for 10 days before the introduction of the mussels.

Test organism and their maintenance

Freshwater mussels (*L. marginalis*) having a body weight of 31 ± 1.62 g, 7 ± 0.53 cm length and 3 ± 0.5 cm breadth were collected from the same lake. The shells were cleaned in the lake water and they were introduced into the experimental mesocosms (E₁ to E₅) at the rate of eight mussels m⁻² *i.e.*, five mussels per mesocosm. The rate of introduction is based on the fact that on average eight mussels m⁻² were obtained on most of the occasions of mussel collection from the lake. No mussels were introduced into the mesocosms, which served as controls (C₁ to C₅). All the mesocosms were maintained up to 60d and no mortality of mussels were seen during the period.

Physico-chemical properties of lake water

The ambient lake water was having an average dissolved oxygen content of 6.3 ± 0.3 ppm, pH 7.5 ± 0.2 ; water temperature 26 ± 2 °C; total alkalinity 72 ± 8 ppm and total hardness 142 ± 12 ppm. More detailed analysis was not carried out as the experiment involved only comparative assessment between control and experimental mesocosms maintained in the same ambient water.

Sediment sampling

In order analyse the selected abiotic ecological factors of the bottom sediment as well as to maintain consistency, three sediment samples each were taken from each of the mesocosms at each sampling interval as scheduled in the Table 1. Sampling was done separately from the experimental as well as control mesocosms after the expiry of

15, 30, 45 and 60d using a core samples of 5 cm diameter and up to a depth of 6 cm. The collected samples were processed separately for each of the parameter as given below.

Table 2. One-way analysis of variance showing significant alterations in the percentage of water content of the sediment, percentage of organic matter, percentage of total nitrogen, total phosphorus and humic acid content of the bottom sediment of mesocosms at different intervals of the experiment

Source	Sum square (ss)	df	Mean square (ms)	F	P
Percentage of water content in the sediment					
Total	287.81	14			
Between groups	279.44	04	69.86	83.46	< 0.001
Within groups	8.37	10	0.83700		
Percentage of organic matter in the sediment					
Total	16.98	14			
Between groups	16.90	04	4.23	528.75	< 0.001
Within groups	0.08	10	0.00800		
Percentage of total nitrogen in the sediment					
Total	0.8286	14			
Between groups	0.7828	04	0.1957	42.73	< 0.001
Within groups	0.0458	10	0.00460		
Total phosphorus in the sediment					
Total	0.0355	14			
Between groups	0.0346	04	0.0087	96.67	< 0.001
Within groups	0.0009	10	0.00009		
Humic acid content of the sediment					
Total	0.2563	14			
Between groups	0.2537	04	0.0634	243.85	< 0.001
Within groups	0.0026	10	0.00026		

Sediment analyses

In order to quantify to selected ecological factors, three sediment samples each from each of the three respective mesocosms (Table 1) were used at each sampling interval. Percentage of water content of sediment, percentage of total nitrogen and total phosphorus content of the sediment were estimated by following the method of Murugesan and Rajakumari (2005). While percentage of organic matter present in the sediment was calculated by following Trivedy *et al.* (1998), humic acid content of the soil was estimated by following Oviasogie and Unuigbo (2006) and Parthasarathi *et al.* (2007).

Statistical analysis

In order to ascertain whether the parameters measured were significantly influenced by the activity of *L. marginalis* at various time intervals, the data collected from the control and experimental mesocosms were subjected to one way analysis of variance (ANOVA) followed by Duncan's multiple range test (Tables 2 and 3). Since each category of parameters collected from the control mesocosms did not vary significantly during the entire period of the experiment, the overall averages of each of them were taken into account.

RESULTS

In order to understand the ecological significance of biodeposition and bioturbation, the various soil parameters analysed in the lake mesocosm study included percentage of water content of the soil, percentage of organic matter, percentage of total nitrogen, total phosphorus and humic acid content.

Percentage of water content

The water content of the bottom sediment of the experimental mesocosms was found to be greatly influenced by the presence of *L. marginalis* when compared to that of the control ones (Tables 2 and 3). The percentage of water content was steadily increasing up to 30d of experimentation (Tables 2 and 3; $p < 0.01$). However after 30d, it remained more or less at the same level through out the experiment. No significant change in the percentage of water content was noticed in the control mesocosms.

Table 3. Alterations in the percentage of sediment water content, percentage of organic matter, percentage of total nitrogen, total phosphorus and humic acid content of the bottom sediment of the mesocosms at various intervals of the experiment

Control	15d	30d	45d	60d
Percentage of water content in the sediment				
40.65 \pm 0.16	45.78 \pm 0.52 a**	52.24 \pm 0.28 a** b**	50.75 \pm 0.93 a** b ^{NS}	50.96 \pm 0.40 a** b ^{NS}
Percentage of organic matter in the sediment				
1.11 \pm 0.033	1.8 \pm 0.038 a**	3.33 \pm 0.012 a** b**	2.84 \pm 0.046 a** b**	4.08 \pm 0.047 a** b**
Percentage of total nitrogen in the sediment				
1.66 \pm 0.0360	1.92 \pm 0.0404 a**	2.06 \pm 0.0289 a** b*	2.11 \pm 0.0549 a** b ^{NS}	2.35 \pm 0.0284 a** b**
Total phosphorus in the sediment				
0.19 \pm 0.0033	0.20 \pm 0.0033 a ^{NS}	0.22 \pm 0.0058 a** b*	0.27 \pm 0.0067 a** b**	0.32 \pm 0.0058 a** b**
Humic acid content of the sediment				
0.3033 \pm 0.0033	0.330 \pm 0.0058 a ^{NS}	0.4066 \pm 0.0088 a** b**	0.4933 \pm 0.0088 a** b**	0.6633 \pm 0.0145 a** b**

Note: $\bar{X} \pm \text{SEM}$ (Duncan's multiple range test); a = between the respective experimental group and control group; b = between the respective experimental group and the preceding experimental group; d = days; NS = not significant; * = $p < 0.05$; ** = $p < 0.01$.

Percentage of organic matter

The organic matter content was also increasing up to 30d in the experimental mesocosms. But after 45d it decreased significantly (Tables 2 and 3; $p < 0.01$). However, in contrast to the percentage of water content, the organic matter again registered a significant increase after 60d. There were no significant changes in the organic matter contents of the control mesocosms.

Percentage of total nitrogen

In contrast to the percentages of water content and organic matter, the percentage of total nitrogen in the experimental mesocosms showed a steady increase throughout the experiment (Tables 2 and 3) reaching the maximum after 60d. No significant changes in the nitrogen content were noticed in the control mesocosms.

Total phosphorus

The phosphorus content of the experimental mesocosms also increased gradually (Tables 2 and 3) reaching the maximum after 60d ($p < 0.01$). The increase was however not significant during the initial stage (*e.g.*, 15d). The phosphorus content of the control mesocosms was more or less same throughout the tenure of the experiment.

Humic acid content

The humic acid content (Tables 2 and 3) in the experimental mesocosms remained more or less at the control level up to 15d and after that it started an increasing trend to reach the maximum value of 0.6633 ± 0.0145 after 60d ($p < 0.01$). As in the case of the other ecological parameters, humic acid content in the control mesocosms remained statistically unchanged. From 30d onwards, highly increased quantities of muscilaginous scum/organic debris rich in algal cells were also seen on the walls and bottom sediments of the mesocosms.

DISCUSSION

The findings of the present study clearly indicate the significant ecological roles played by the freshwater mussel *L. marginalis* in the freshwater ecosystems through bioturbation and biodeposition of faeces and pseudofaeces. The ploughing movements of *L. marginalis*, in addition to making the soil more loose and soft, increase the penetration of water into the sediments and bring in more dissolved oxygen and nutrients to the deeper layers of the soil. This finding assumes greater significance due to the fact that the water content of the bottom soil is reported to influence the micro and macro invertebrates in a variety of ways (Vaughn and Hakenkemp, 2001; Vaughn and Spooner, 2006). However, after 30d onwards the percentage of water content remains more or less same in the experimental mesocosms throughout the remaining period of the experiment, but still at a significantly higher level than the control mesocosms (Tables 2 and 3). This is basically because of the fact that percentage of water content might have reached the saturation point. In general, the increase in the percentage of water content in the bottom sediments of the experimental mesocosms as against the control ones is the result of the direct physical habitat modification by the bioturbation process where *L. marginalis* plays an important role.

In filter feeding freshwater bivalves, particle covered by mucus and trapped on the gills are moved forward toward the labial palps by a set of specialized cilia. The palps then convey these materials to the mouth and during this process any excess quantity is dropped into the mantle for expulsion (Dillon, 2000). Such mucous laden particulate materials are known as pseudofaeces. Further, the particles assimilated are only a subset of those ingested and the particles ingested are only a subset of those gets collected by the cilia. The remaining portion is biodeposited as pseudofaeces to the bottom sediments (Dillon, 2000; Vaughn and Hakenkemp, 2001; Christian *et al.*, 2008). In short, removing particles from water column, biodepositing pseudofaeces and faeces along with excretion of nutrient rich excretory materials are some of the nutrients cycling processes being done by the sediment dwelling freshwater bivalves such as *L. marginalis*. Faeces and pseudofaeces are important available organic matters to the aquatic ecosystems and are having a high degradation rate and rapid turnover (Mirto *et al.*, 2000; La Rosa *et al.*, 2002). The active biodeposition of faeces and pseudofaeces by the mussels could be the reason for the increased percentage of organic matter in the experimental mesocosms (Table 3). However, the exact reason for the significant decrease in the organic matter after 45d of the experiment is not clearly known. It is appropriate to note that biodeposition of faeces and pseudofaeces by *L. marginalis* is an important sedimentation process by which high-quality pelagic resources are brought to the bottom soil and thereby contribute to the organic content of the soil.

Again, the accumulation of the excretory products, faeces and pseudofaeces of the mussels might also be primarily responsible for the steady increase in the quantity of total nitrogen and phosphorus in the experimental mesocosms. This observation is in line with the findings that fresh water bivalves produce nitrogen rich hypo-osmotic urine consisting primarily of ammonia (Vaughn and Hakenkemp, 2001), which by bacterial action gets converted into nutrients for primary producers. Along with ammonia, unionids reportedly excrete phosphorus also (Davis *et al.*, 2000; Vaughn *et al.*, 2004; Christian *et al.*, 2008). This observation becomes more credible due to the fact that both nitrogen and phosphorus contents in the experimental mesocosms increase more or less at the same pace. While making comparative studies on the seasonal nutrient cycling by unionid species, various authors have reported that while excretion rates varied seasonally, the direction and magnitude of these changes were species specific (Davis *et al.*, 2000; McMahon and Bogan, 2001; Spooner and Vaughn, 2006). Recently enhancement of denitrification process associated with zebra mussel beds has also been reported (Bruesewitz *et al.*, 2006). In view of all these ongoing discussions, it is quite vivid that the freshwater bivalve mollusc *L. marginalis* plays crucial roles in the ecosystem processes involving nutrient cycling. Epifaunal bivalves such as *Driessena* (zebra mussel) are also known to be important in nutrient cycling (Arnott and Vanni, 1996; Vanni, 2002; Gardner *et al.*, 2001).

Even though the exact source of the increasing quantities of humic acid in the experimental mesocosms at various stages is not clearly understood, benthic microbial mediated disintegration and degradation of the organic matter biodeposited by the mussels may at least be partially responsible for it. Therefore, along with other benthic organisms mussels also would have contributed to the organic disintegration and formation of humic acid. It is also worth mentioning that the significant increases in the humic acid contents of the experimental mesocosms especially in the later half of the experiment is accompanied by the appearance of increasing quantities of mucilaginous

scum/debris containing rich quantities of algal cells. As humic acid is known to play important roles in plant growth (Parthasarathi and Ranganathan, 2002), it might have been contributed to the increased presence of algal cells in the mucous bound debris from 30d onwards. Further, according to Watson *et al.* (1997) biodeposition of nutrient rich organic matter can also increase the algal population. Accumulation of the mucous laden pseudofaeces could be responsible for the appearance of the scum to a great extent.

CONCLUSION

It may be summarized that the freshwater bivalve *L. marginalis* through the processes of biodeposition and bioturbation, could alter the physical and chemical properties of the habitat and thereby play critical roles in managing the availability of resources to other organisms *e.g.*, primary producers. As organisms that control the availability of resources to other organisms by physical modifications of habitat, freshwater mussels including *L. marginalis* could appropriately be called as ecosystem engineers. However, they being a threatened species, deleterious anthropogenic environmental alterations could wipe out them leading to unsolicited changes in the process of bioturbation and biodeposition, which in turn could inhibit or alter a number of critical ecosystem functions that occur in the bottom sediment or sediment water interface of freshwater ecosystems.

ACKNOWLEDGMENT

Authors are thankful to Annamalai University authorities for providing lab facilities.

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Received for Publication: 17/08/2008

Accepted for Publication: 26/08/2008

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